



The following article was published in ASHRAE Journal, May 2003. © Copyright 2003 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. It is presented for educational purposes only. This article may not be copied and/or distributed electronically or in paper form without permission of ASHRAE.



Lucile Erwin Middle School features an ASHRAE Technology Award-winning hybrid chilled water/ice thermal storage plant.

Ice Thermal Storage For Colorado School

By **Michael D. Haughey, P.E.**, Member ASHRAE

A hybrid chilled water/ice thermal storage plant for the Lucile Erwin Middle School in Loveland, Colo., has saved more than \$18,000 in energy costs annually. After an evaluation of alternatives and life-cycle analysis, the local power authority offered low-interest financing for the system to the Thompson School District.

However, the decision to implement the plant was made with building construction already well under way, so a major challenge was fitting the system into a space intended for chilled water primary and distribution pumps and a space for an outdoor chiller. A factory-built, skid-mounted pump, valve, and control package solved this problem. Chilled water and ice production began with the

school's opening in August with the controls system partially in manual mode.

Commissioning the complete plant was delayed due to weather. All parties were brought back onto the project in later seasons to resolve issues and complete final details to make the system fully operational as intended. The goal of optimizing demand savings was delayed until everything was operating as

intended and resulted in exceeding expectations by completely eliminating chiller demand from the utility bill.

The project uses a flexible ice thermal storage system concept with a demand-limit-controlled, chiller priority, partial-storage system. The design features a factory-packaged pump, valve, and PLC-based energy management system to control the chilled water/ice storage plant.

The plant is comprised of a 103-ton (360 kW) capacity air-cooled chiller and 107 tons of chilled water capacity available from the ice storage and 860 ton-hours (3025 kW) of latent ice storage

About the Author

Michael D. Haughey, P.E., is vice president, engineering with E-Cube in Boulder, Colo.

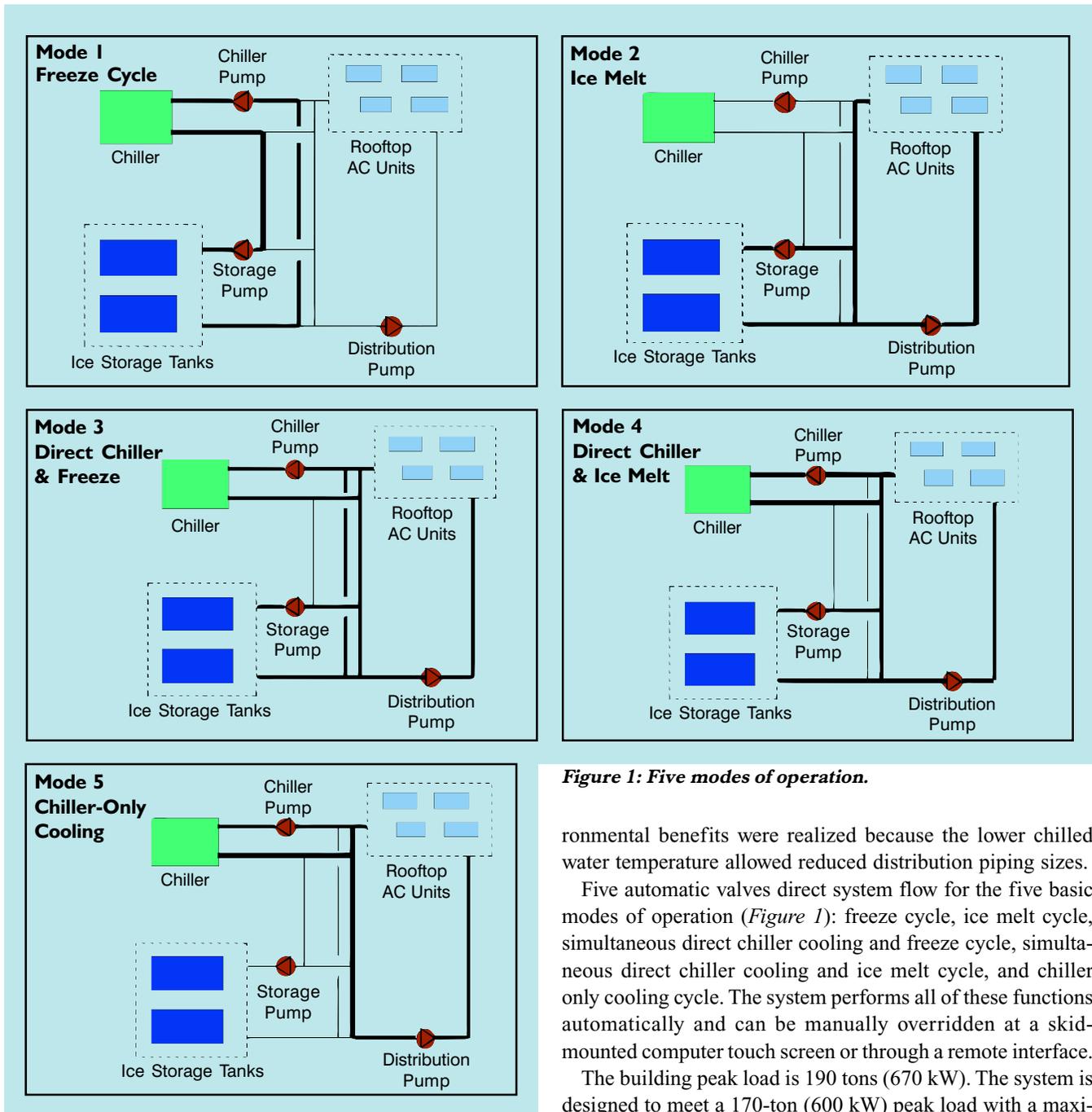


Figure 1: Five modes of operation.

capacity divided between two tanks. The chiller has a freezing capacity of 84 tons (28 kW) and can charge the storage system in approximately 12.5 hours.

The chiller system uses about 40% less electrical demand than a chilled water system without thermal storage because of the smaller chiller. Also, the system monitors building electrical demand and uses ice to reduce demand during peak times by modulating back the chiller while automatically increasing cooling provided from ice storage. Further cost and envi-

ronmental benefits were realized because the lower chilled water temperature allowed reduced distribution piping sizes.

Five automatic valves direct system flow for the five basic modes of operation (*Figure 1*): freeze cycle, ice melt cycle, simultaneous direct chiller cooling and freeze cycle, simultaneous direct chiller cooling and ice melt cycle, and chiller only cooling cycle. The system performs all of these functions automatically and can be manually overridden at a skid-mounted computer touch screen or through a remote interface.

The building peak load is 190 tons (670 kW). The system is designed to meet a 170-ton (600 kW) peak load with a maximum chilled water plant demand of 143 kW, consisting of 134 kW for the chiller and 9 kW for pumps. The average energy consumption of the system is designed to be less than 1.5 kWh per ton-hour delivered to the load. The client benefits from a huge electrical demand savings right away, since the design uses a 105-ton (370 kW) capacity chiller where a traditional design would require a 190-ton (670 kW) unit.

Utility bills show that the system is able to completely ride through building peaks on ice alone for demand savings up to 296 kW. The demand savings more than offset unrealized



consumption savings, virtually a wash at $-7,205$ kWh. Accounting for the improved demand savings from actual utility bills, the data show a total savings of \$18,284 per year for a payback period of 4.1 years.

The controls were designed to ensure that the flexibility existed to adjust to cooling demands as well as possible future rate structure changes. The system reduces O&M and maximizes chiller use while at the same time not allowing the chiller to add to building demand peak unnecessarily. This was achieved partially by programming in the differential kW by which building demand would need to drop before the chiller could be restarted (after being demand limited). Two factors contributed to this ability:

1. The commissioning specifications were coordinated closely with the commissioning agent to ensure every detail of the systems, equipment, control sequences, and monitoring was checked, corrected, fine-tuned, and modified where necessary. Though commissioning this hybrid system was more involved, the result is excellent functionality; and

2. The system features only one chiller, as compared to the base bid, lowest cost alternative system (which comprised 13 rooftop DX units, each with a separate refrigeration system to be maintained). In comparison with a typical chiller system, operating this chiller to make ice mostly at night will extend its life.

This ice storage system results in optimized energy efficiency by carefully avoiding electrical demand peaks caused by the system. The features that contribute to the system's performance advantages include:

1. The cooling system is designed to operate in five modes, which is three more than most small ice storage systems. For each mode, only the necessary pumping energy is used since pumps are dedicated for each system component. This is an energy-saving advantage over systems that pump through the chiller when only using the ice tanks and over systems that pump through the ice tanks when only using the chiller.

2. VFDs provide significant pumping energy savings, especially on the distribution system, which is rarely at full load, and on the ice storage system when cooling the building either fully from ice or supplementing the chiller. The separate ice storage pump does not waste energy pumping through the chiller when cooling only with ice, as is the case with systems having a common chiller-ice pump.

3. The added feature of controlling the chiller's leaving water temperature, even in ice-making mode, improves system reliability and chiller life by allowing the chiller to operate in a stable mode when one of the tanks is out of service for maintenance or when a valve is closed inadvertently. Using a rotary screw chiller specially designed to have positive oil return in ice mode under partial load conditions enables the leaving-water-temperature control while safeguarding the chiller.

The chiller/storage match is designed for continuous chiller operation at about 22°F (-6°C) chilled water supply temperature under normal conditions for optimum chiller performance. In contrast, many systems run the chiller at 100% in ice mode, leaving the chiller discharge temperature up to the thermodynamic match between chiller capacity and ice stor-

Advertisement in the print edition formerly in this space.

age charge rate. A given size chiller matched with two different storage capacities (or tank sizes) will have a lower discharge temperature in the smaller system. If a system has two tanks and one is out of commission, the system will likely run down to the low limit and cycle off for the night or, worse, operate from the low-limit control. If there is no low-limit control, or if the low limit fails from overuse, the chiller compressor may be damaged.

4. Operating efficiency is gained by freezing ice during Colorado's cool nights and by running the chiller solo during the morning when it's still cool outside.

5. The project is designed for a fifth mode that allows simultaneous chiller cooling and ice making to accommodate evening events. It also allows the system to go into freeze cycle when an RTU has inadvertently been left in occupied mode for the night, which otherwise would prevent the freeze cycle from occurring that evening.

This project demonstrates an ice-storage system that saves electrical demand can have a faster payback than anticipated if the system and controls design is flexible and the project is meticulously commissioned. The actual energy rate has declined while the demand charge has increased from the rates available when the energy study was done. A flexible system that has easily adjustable and responsive demand limiting controls can optimize savings even taking advantage of coincident utility demand charges. With demonstrated ability to run on ice during daily peaks, the system is exhibiting the ability to far exceed the power authority's goal for reducing demand on the utility during peaks.

The system has also been able to handle increased ton-hours of load without increasing demand usage. The building has seen loads beyond those anticipated in the energy study from operational patterns including computers left on at night, lights left on longer for cleaning, and extended use of air handling systems. These are reflected in higher energy usage on the utility bills while the demand charges remain lower than predicted, as confirmed by a graphical comparison of actual utility bills to the simulation data.

Since the energy consumption cost of stored ice cooling can average slightly more than that of direct chilling, an operating strategy was developed to provide as much direct chilling cooling as possible while limiting the monthly on-peak demand. In the future, additional savings could be realized if a time-of-day rate schedule or a ratchet clause takes effect.

Acknowledgments

Credit and thanks for their roles in making this project a success go to Thompson School District, Loveland Water & Power, Platte River Power Authority, The RMH Group, E-Cube, Inc, U. S. Engineering, Systecon, Johnson Controls, Onicon, Baltimore Air Coil, and The Trane Company. ●

Advertisement in the print edition formerly in this space.